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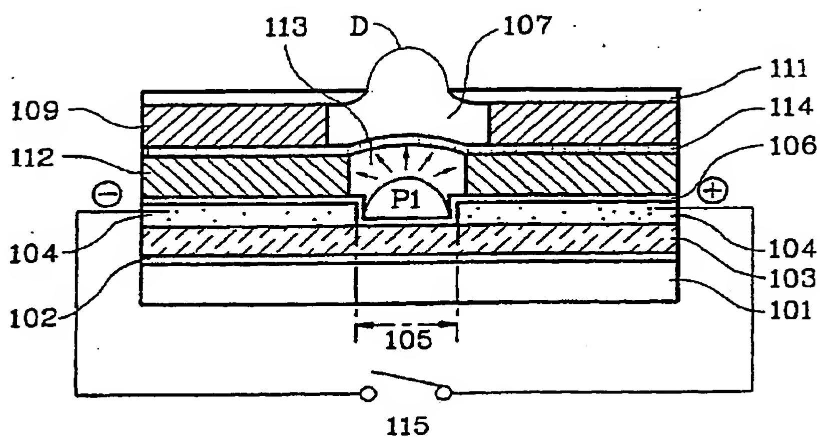
(54) Ink spraying device and method

(57) The invention provides an ink-jet printing head comprising an ink chamber having an orifice through which ink is ejected and working fluid chamber separated from the ink chamber by a thermally conductive and thermally expansive membrane and having first and second electrodes, electrically isolated from each other and adapted to pass current through a resistor positioned spaced from and opposite the membrane so as to create bubbles in the working fluid thus to deform the member so as to eject ink through the orifice. A method of spraying ink is also provided.

FIG. 9



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Description

Background of the Invention

The present invention relates to a spray device for an ink-jet printer and an ink spraying method for an ink-jet printer.

Firstly, the structure and operation of a conventional ink-jet printer will be described below with reference to FIG.1.

An ink-jet printer has a CPU 10 for receiving a signal form a computer (not shown) through a printer interface. The CPU reads a system program from EPROM 11 which stores an initial value set for operating the printer and the system. The CPU outputs a control signal according to the program content. ROM 12 holds a control program and several fonts. RAM 13 temporarily stores data during the operation of the systems. An ASIC circuit part 20, in which most of the CPU-controlling logic circuits are realized in an ASIC form, transmits data from CPU 10 to the majority of the circuits around CPU 10. A head driver controls the operation of an ink cartridge 31 in response to the control signal of the CPU 10 which is transmitted from the ASIC circuit part 20. A maintenance driving circuit 40 protects the nozzle of the ink cartridge 31 from exposure to air and drives a driving circuit of a maintenance motor 41. A carriage motor driving circuit 50 controls the operation of a carriage return driving motor 51. A line feed motor driving circuit 60 controls the operation of line feed motor 61 for feeding/discharging paper by using a stepping motor.

Conventionally, a method of applying a printing signal from the computer through the printer interface to drive each motor 40, 50 and 60 according to the control signal of the CPU 10 is used to perform printing. Here, the ink cartridge 31 sprays fine ink drops through a plurality of openings in the nozzle, and thus forms dots.

Ink cartridge 31 will be described in detail.

As illustrated in FIG. 2, the ink cartridge includes a head 3. Ink 2 is absorbed through a sponge in case 1 which forms the external profile of the container.

As illustrated in FIG. 3, the head 3 has a filter 32 for eliminating impurity materials mixed with the ink. An ink stand pipe chamber 33 contains ink filtered through the filter 32. An ink via 34 supplies ink transmitted through the ink stand pipe chamber 33 to an ink heating part and a chip 35 having a chamber. A nozzle plate 36 has a plurality of orifices for expelling ink transmitted from the ink via 34, from the heating part (not shown) to a print media.

As illustrated in FIG. 4, the head 3 includes the ink via 34 for supplying ink to an ink chamber (not shown) between the nozzle plate 36 and the chip 35. A plurality of ink channels 37 supplies ink from the ink via 34 to each opening of the nozzle plate 36. A plurality of spraying parts 35 is provided for spraying ink transmitted through the ink channels 37. A plurality of electrically connecting means 38 is provided for supplying power to the plurality of chips 35.

As illustrated in FIG. 5, the head 3 includes a resistor layer 103 formed on an oxide layer (SiO_2) 102 on a silicon substrate 101 by an oxidation process when heated by electrical energy. Two electrodes 104 and 104' formed on the resistor layer 103 one provided with an electrical connection. A protective layer including several layers is provided for preventing the heating part 103 formed on resistor layers 104 and 104' and resistor layer 103 from being etched and deformed by a chemical reaction with the ink. An ink chamber 107 is provided for generating bubbles in the ink from the heat of the heated part 105. An ink channel 108 allows ink to flow from the ink via to the ink chamber 107. An ink barrier 109 plays the role of a wall to form a space used for leading ink transmitted through the ink channel to the ink chamber 107. A nozzle plate 111 has a plurality of orifices 110 for spraying ink pushed out as a result of the volume variation caused by generation of bubbles in the ink chamber 107.

Nozzle plate 111 and the heated portion 105 are spaced apart at regular intervals to face each other. A pair of electrodes 104 and 104' are connected to an externally electrically connected terminal bumper (not shown) and this bumper is connected to a head controller (not shown) so that the ink is sprayed from each position through the nozzle openings.

Each of the heating portions has an ink barrier 109 for guiding the ink from the side, and this ink barrier 109 is connected to a common ink via to guide the ink from the ink container.

The conventional ink spray device sprays as follows.

Head driver 30 transmits electrical energy to a pair of electrodes 104 and 104' placed where the desired characters will be printed in response to the control command of CPU 10 which receives the printing command through the printer interface. Power is transmitted through the two electrodes 104 and 104' to heat heating portion 105 with a JOULE heat for a predetermined time ie by electrical resistance heat, namely, $P=I^2R$. The surface of the heating portion 105 is heated up to 500 to 550°C, and heat is conducted to the plurality of protective layers 106. At this point heat is applied to the ink in wetting contact with the protective layers. The distribution of the bubbles generated by the vapour pressure is highest in the centre, regarding the centre of the heating part 105 about a symmetrical axis. By the heat, ink is heated and bubbles are formed, so that the volume of the ink on the heated portion part 105 is changed by the vapour pressure. Ink is pushed out by this volume variation through the openings 110 of nozzle plate 111.

At this time, if the electrical energy supplied to the two electrodes 104 and 104' is cut off, the heating part 105 is momentarily cooled and the expanded bubbles contract, thereby returning the ink to its original state.

The ink, expanded and discharged out of the openings of the nozzle plate, is sprayed onto print media in

the form of a drop due to the surface tension, and this forms an image. Due to the internal pressure drop following the decrease in volume of the bubbles, ink is recharged from the container via the ink via.

The above-mentioned conventional ink spraying method has the following problems.

Firstly, when bubbles are formed by a high temperature so as to spray the ink, the content of the ink may be affected by the thermal variation. The life of the internal components is decreased due to the impact wave from the bubbles. These may cause dissatisfactory use instead of the desired high quality printing.

Secondly, the ink, the protective layer 106 of the resistor 103 and the two electrodes 104 and 104' inter-act electrically with each other, and, accordingly, corrosion occurs by ion exchange at the border layer of the heating part 105 and the two electrodes 104 and 104', thereby decreasing the lifetime of the head.

Thirdly, as bubbles are made in the ink barrier containing the ink, the recharging time cycle is lengthened due to its impact.

Fourthly, the shape of the drop affects its direction of travel its roundness and the uniformity of the quantity of ink in the drop according to the shape of the bubbles, and therefore this affects the printing quality.

An improved conventional spraying method contrived to alleviate those problems has been developed. This will now be described.

As illustrated in FIG. 7, the nozzle plate has openings which serve as orifices for the ink spray. A flexible membrane 204 made of rubber silicone is installed across the nozzle plate 206 and therefore forms the ink chamber 207 temporarily containing the ink with the ink barrier 205. Two electrodes 202 and 202' and a resistor 203 are placed under the membrane 204. Resistor 203 is laid at the centre of the two electrodes 202 and 202'.

Liquid is supplied to a second space 208 formed between the membrane 204 and the resistor 203 by the capillaries caused due by the surface roughness.

A voltage pulse transmitted to the resistor 203 through the electrodes 202 and 202' heats and evaporates the liquid in the second space 208. By this vapour pressure, the flexible elastic material of the membrane 204 is deformed. In response to the deformation of the membrane 204, ink in the upper ink chamber 207 is sprayed through the nozzle openings. Ink is sprayed, using deformation of the membrane 204 not by the thermal deformation, but deformation in response to the generation of bubbles ie the vapour pressure of the liquid trapped in the space 208 in the state when the surfaces of the resistor 203 and the membrane 204 are directly adjoined.

In this technique, the membrane is made of flexible rubber silicon and therefore has a low heat-conductivity. Consequently, it takes long time to return it to the original state after the expansion, and it affects the ink supply speed and slows down the entire printing speed.

Summary of Invention

Preferably, there is provided an ink-jet printing head comprising: an ink chamber having an orifice through which ink is ejected; a heating chamber containing a working fluid separated from the ink chamber by a thermally conductive and thermally expansive membrane; and first and second electrodes, electrically isolated from each other and adapted to pass current through a resistor positioned spaced from and opposite the membrane so as to create bubbles in the working fluid thus to deform the membrane so as to eject ink through the orifice.

Preferably, the membrane is subject to deformation on cooling. Preferably, the membrane is subject to deformation resulting from the difference in the rate of cooling of the side of the membrane facing the ink chamber and that of the side of the membrane facing the heating chamber when the power is cut off.

Preferably the membrane is adapted to project temporarily into the heating chamber on cooling.

Preferably, there is provided a head according to claim 1, in which the membrane is substantially opposite the orifice.

Preferably, there is provided a head in which the resistor, or a layer covering the resistor, constitutes an inner face of the working fluid chamber opposite the orifice. Preferably, there is provided an ink-jet printer head, in which a protective layer is provided to separate the electrodes and resistor from the working fluid.

Preferably, there is provided a head, in which the first and second electrodes are formed adjacent a resistor layer constituting the resistor.

Preferably, there is provided a head, in which the electrodes are formed on the resistor layer and the space between the electrodes forms part of the heating chamber.

Preferably, there is provided an ink-jet printer head, in which an insulating layer of predetermined thickness is provided to space the membrane from the resistor and to provide walls of the heating chamber.

Preferably, there is provided a head in which the membrane covers the insulating layer and the heating chamber so as to seal the working fluid in the heating chamber.

Preferably, there is provided an ink-jet printer head comprising an ink barrier formed above the membrane and serving as a wall of the ink chamber and for forming a flow channel which guides ink into the ink chamber.

Preferably, in use, the ink chamber is uppermost and the working fluid chamber is lowermost.

Preferably, there are a plurality of ink chambers and corresponding working fluid chambers and a nozzle plate if formed on the ink barrier having a plurality of openings for spraying the ink in the ink chamber onto print media. Preferably, the membrane extends across and seals a plurality working fluid chambers.

Preferably, the working fluid has a high tempera-

ture-conductivity. Preferably the working fluid has a high vapour pressure. Preferably the working fluid comprises fluorinate.

Preferably, the membrane is adapted to have a high temperature conductivity. Preferably the membrane is adapted to have good thermal expansion properties.

Preferably, the membrane comprises a thin film. Preferably, it is a thin metal film.

Preferably the membrane contains one or more of Ag, Al, Cd, Cs, K, Li, Mg, Mn, Na, Zn.

A preferred embodiment of the present invention is a spray device for an ink-jet printer, in which the spraying speed is enhanced by dividing an ink chamber area into an ink chamber and a heating chamber using, preferably, a thin metal film membrane.

Preferably a spray device is provided with means for heating a heating part, using for example, electrical energy transmitted to individual electrodes, deforming a membrane using thermally expanding liquid and spraying ink on to a print media according to the flow of the membrane.

Preferably, the membrane is a composite of one or more metals and an organic material.

Preferably, there is provided a head in which one of the surfaces of the membrane seals the working fluid chamber and the other makes contact with the ink and is wet.

Preferably, there is provided a head in which one surface of the membrane is in contact with gas and the other surface of the membrane is in contact with ink.

Preferably, there is provided a head in which the working fluid is liquid, gas or a mixture of the liquid and gas. For example, when the working fluid chamber is lowermost, the lowermost surface of the membrane is in contact with gas even if working fluid liquid is present, and not in wetting contact with the working fluid liquid.

Preferably, there is provided a head in which as the heating chamber cools the volume of membrane varies and the membrane retracts towards the heating chamber opposing the decreasing of the pressure in the heating chamber and due to a contracting force generated in the membrane on the surface cooled by the ink so that it generates an absorbing force, and ink is drawn into the ink chamber as a result.

Preferably, the sides of the membrane making contact with the ink and with the heating chamber, have a difference in their contracting rate on cooling so that the membrane is elastically deformed over a predetermined area towards the direction to the heating chamber by the inertia force, so as to generate a momentary absorbing force to draw ink into the ink chamber.

Preferably, there is an inlet for allowing the working fluid to flow into the heating chamber, and in which a bending operation can be performed to seal the inlet.

Preferably, there is provided a method of ejecting ink from an ink-jet printer head as described herein comprising:

heating or cooling liquid in the heating chamber so bubbles are created in the heater chamber thus to deform the membrane so as to spray ink out of the orifice.

Preferably, there is provided a spray device of an ink-jet printer of the invention which includes a resistor layer formed on an oxide layer (SiO_2) generated by an oxide surface treatment on a silicon substrate. Preferably electrodes are formed on the resistor layer in pairs for supplying electrical energy of a different polarity. Preferably a heating layer is formed in a portion of the resistor layer which is heated with heat generated from the resistor layer with the different polarity of electrical energy supplied to the two electrodes. Preferably, there is a protective layer or multi-layer for preventing the surface of the two electrodes and the heating layer from being corroded by contact of an oxide with air. Preferably, there is an insulating layer for surrounding the protective layer to form a predetermined space on the heating layer. Preferably, there is a heating chamber formed by the insulating layer and for containing working fluid which is heat-expanded by the heat generated from the heating layer. Preferably, there is a membrane for covering the insulating layer and the heating chamber to thereby seal a plurality of heating chambers, and having a volume variation according to the bubbles generated by a heat-expansion when the inside of the heating chamber is heated by the heat from the lower heating layer. Preferably, there is an ink barrier formed on the membrane and serving as a wall for forming a flow guide line which guides ink from an ink via through an ink channel. Preferably, an ink chamber is formed between the ink barrier on the membrane for containing the ink transmitted from the ink channel. Preferably, a nozzle plate is formed on the ink barrier and the ink chamber. The nozzle plate may have a plurality of openings for spraying the ink in the ink chamber towards the print media. Preferably, there are electrical connecting means for supplying electrical energy of different polarity to the pair of electrodes.

Brief description of the attached drawings

Preferred embodiments of the invention will now be described, by way of example only with reference to the drawings.

FIG. 1 is a block diagram illustrating the structure of a conventional ink-jet printer.

FIG. 2 is a schematic sectional view of an ink cartridge of a conventional ink-jet printer.

FIG. 3 is an enlarged sectional view of a head in a conventional spray device.

FIG. 4 is a plan sectional view taken along lines E-E of FIG. 3 from the direction of A.

FIG. 5 is an enlarged sectional view of a conventional spray device taken along line F - F of FIG. 4 from the direction of B.

FIG. 6 is an exemplified view of the conventional ink spray mechanism.

FIG. 7 is an enlarged sectional view of an improved

conventional spray device.

FIG. 8 is an enlarged sectional view of a spray device of the invention.

FIG. 9 illustrates expansion of a membrane in the spray device of the invention.

FIG. 10 illustrates contraction of the membrane in the spray device of the invention.

Detailed description of the preferred embodiment

In FIG. 8, the same reference numerals are allocated to the same features as in FIGS. 5 and 6.

The spray head of the invention includes a resistor layer 103 formed on an oxide layer (SiO_2) 102 generated by an oxide surface treatment of a silicon substrate 101. Electrodes 104 and 104' formed on the resistor layer in pairs supply electrical energy of different polarity. Heating layer 105, which is part of resistor layer 103, is heated with the heat generated from the resistor layer 103 when electrical energy is supplied to the two electrodes 104 and 104'. A protective layer 106 is provided on top of the heating layer 105 and 104 and 104 to prevent the exposed surfaces from being corroded by oxiding contact with air. An insulating layer 112 and surrounds the protective layer to form a predetermined space around the heating portion 105. A heating chamber 113 is formed by the insulating layer 112. Chamber 113 contains working fluid which is thermally expanded by the heat generated from the heating layer 105. A membrane 114 covers the insulating layer 112 and contains the working fluid. The membrane 114 covers the insulating layer 112 and the heating chamber 113 to seal a plurality of heating chambers 113. The membrane deforms in response to the volume variation when bubbles are generated by a heat-expansion when the inside of the heating chamber is heated by the heat from the lower heating part 105. An ink barrier 109 formed on the membrane 114 serves as a wall for forming a flow guide which guides ink from an ink via through an ink channel. An ink chamber 107 is formed between the ink barrier 109 on the membrane 114 and it contains the ink transmitted from the ink channel. A nozzle plate 111 is positioned on the ink barrier 109 and the ink chamber 107 opposite the print media. An electrical connection means 115 is provided for supplying different polarity of electrical energy to the pair of electrodes 104 and 104'.

The membrane 14 is made from a thin film having a high heat conductivity such as a metallic thin film. The film contains, preferably, one or more of the following materials: Ag, Al, Cd, Cs, K, Li, Mg, Mn, Na, Zn. The metals and organic material of the membrane are chosen to increase its lifetime.

Liquid such as fluorinate with a high temperature conductivity and a high vapour pressure is supplied into the heating chamber 113. In the heating chamber, an inlet for implanting liquid is formed (not shown), and a bending process is performed to seal this inlet.

In the embodiment shown, the resistor layer 103 is positioned beneath the electrodes 104 and 104' so a recess is provided between the electrodes. It will be understood, though this is less preferred, that a resistor could be provided between the electrodes of, say, approximately the same thickness as the electrodes or the electrodes may be positioned below the resistor layer.

Contrary to the conventional spray device illustrated in FIGS. 5 to 7, the ink chamber area is divided into an ink chamber 107 and a heating chamber 113 by the membrane 114.

The ink chamber is divided by the membrane 114 to alleviate the conventional problems which resulted from heating the ink with the heating part. That is, it is to prevent the corrosion generated from the contact of the ink with the heating layer and to protect the heating layer from the spraying impact after the generation of bubbles.

The invention operates as follows. FIG. 9 illustrates the state where power is applied to two electrodes 104 and 104'. When performing a printing job at a desired position, the head driver (not shown) supplies an electrical signal energy to the corresponding electrodes. The electrical connecting means 115, supplies power of differing polarity to the corresponding electrodes 104 and 104'. Heat is generated in the heating portion 105 by the supplied electrical energy, and this heat is transferred, through a working fluid in the heating chamber 113, to the membrane 114 which is a thin film made of a metal composed material with good thermal expansion properties. Accordingly, when it is exposed to heat, the membrane expands in a longitudinal direction. The working fluid is liquid, gas or a mixture of liquid and gas.

Simultaneously, the vapour pressure which thermally expands in the sealed space of the heating chamber pushes out the membrane 114. The deformed membrane pushes the ink in the ink chamber 107 through the openings 110 of the nozzle plate 111. The reason is that the working fluid in the heating chamber 113 is expanded by the heat and its pressure P1 is greater than the initial pressure so that the membrane 114 is pushed out when power is not applied.

An ink drop pushed out of the openings 110, as illustrated in FIG. 10, is divided in the direction of media from the ink remaining in the ink chamber when the electrical energy provided to two electrodes 104 and 104' is cut off. The membrane 114, which has a high temperature conductivity, is cooled by the ink on its upper surface and by a metallization layer on the substrate through the working fluid in the heating chamber which has a high temperature conductivity. The membrane has a volume variation in the direction of the heating chamber at a time point due to the speedy cooling of its surface on the ink chamber side. Therefore, in the ink chamber, an absorbing force is generated and ink is drawn in. This phenomenon is called a bucking phenomenon.

In other words, when the working fluid in the heating chamber 113 thermally expands, an ink drop is pushed

out of the opening 110 by the deformed membrane 114 and is separated from the opening 110 by the cut-off of the electrical energy supply to the two electrodes 104 and 104', the temperature decreases in the heating chamber 113, and an absorbing force generated from the cooling deformation of the membrane 114.

The upper surface of the membrane 114, namely, the surface wetted to the ink in the ink chamber 107 interacts with the ink in the ink chamber 107, so that the heat is easily lost and the inertia energy required to return the deformed membrane to the original state becomes greater.

The lower surface, namely the surface making contact with working fluid in the heating chamber 113, has a relatively low elasticity and therefore relatively low impetus to return to the original state. This is because there is a difference in the contracting rate as a result of the heat variation between the surface making contact with the ink and with the heating chamber.

Therefore, the pressure P2 in the heating chamber 113 becomes smaller with respect to the initial air pressure PO in the heating chamber 113 in response to the power transmitted to two electrodes 104 and 104' being cut off. Even though the pressure P2 may still be greater than the air pressure PO in the ink chamber, the membrane 114 deforms in an opposing direction due to the elasticity forces in a predetermined area of the membrane. The membrane deforms towards the heating chamber by the inertia force, so that the membrane causes a momentary absorbing force in the ink chamber. Accordingly, the ink drop is separated from the openings 110 due to the surface tension effects of the ink remaining in the ink chamber and is sprayed onto the print media.

As described above, the invention controls the vapour pressure generated by the thermal expansion of a working fluid in a heating chamber, and thus sprays ink in response to the deformation of a membrane. The invention can alleviate the corrosion generated by the contact between ink and the protective layer, and also alleviates damage to the protective layer by the impact generated when the bubbles are sprayed to the openings, thereby improving the quality of the printing.

The sudden deformation of the membrane towards the heating chamber by the longitudinal compression force generated in the membrane in contact with the ink in the ink chamber, enhances the spraying speed.

Claims

1. An ink-jet printing head comprising an ink chamber having an orifice through which ink is ejected and a heating chamber containing working fluid separated from the ink chamber by a thermally conductive and thermally expansive membrane and having first and second electrodes, electrically isolated from each other and adapted to pass current through a resistor positioned spaced from and opposite the membrane so as to create bubbles in the working fluid thus to deform the membrane so as to eject ink through the orifice.

2. A head according to claim 1, in which the membrane is subject to deformation on cooling.

3. A head accordance to claim 2, in which the membrane is subject to deformation resulting from the difference in the rate of cooling of the side of the membrane facing the ink chamber and that of the side of the membrane facing the heating chamber when the power is cut off.

4. A head according to claim 1, 2 or 3 in which the membrane is adapted to project temporarily into the heating chamber on cooling.

5. An ink-jet printer head according to any preceding claim in which an insulating layer of predetermined thickness is provided to space the membrane from the resistor and to provide walls of the working fluid chamber.

6. A head according to claim 5, in which the membrane covers the insulating layer and the working fluid chamber so as to seal the working fluid chamber.

7. A head according to any preceding claim, in which the first and second electrodes are formed adjacent a resistor layer constituting the resistor.

8. A head according to claim 7, in which the electrodes are formed on the resistor layer and a space between the electrodes forms part of the working fluid chamber.

9. A head according to any preceding claim, in which the working fluid has a high temperature-conductivity.

10. A head according to any preceding claim, in which the membrane is a thin film.

11. A head according to any preceding claim, in which the membrane comprises one or more metals and an organic material.

12. A head according to any preceding claim in which the membrane comprises one or more of Ag, Al, Cd, Cs, K, Li, Mg, Mn, Na, Zn.

13. A head according to any preceding claim, in which one of the surfaces of the membrane seals the working fluid chamber and the other makes contact with the ink and is wet.

14. A head according to any preceding claim, in which the working fluid is gas or a mixture of liquid and gas.

15. A head according to claim 14, in which one surface of the membrane is in contact with gas and the other surface of the membrane is in contact with ink.

16. An ink-jet printing head according to any preceding claim, comprising an ink barrier formed on the membrane and serving as a wall for forming a flow channel which guides ink into the ink chamber.

17. A head according to any preceding claim, in which an inlet for allowing the working fluid to flow into the heating chamber is formed, and a bending operation is performed to seal the inlet.

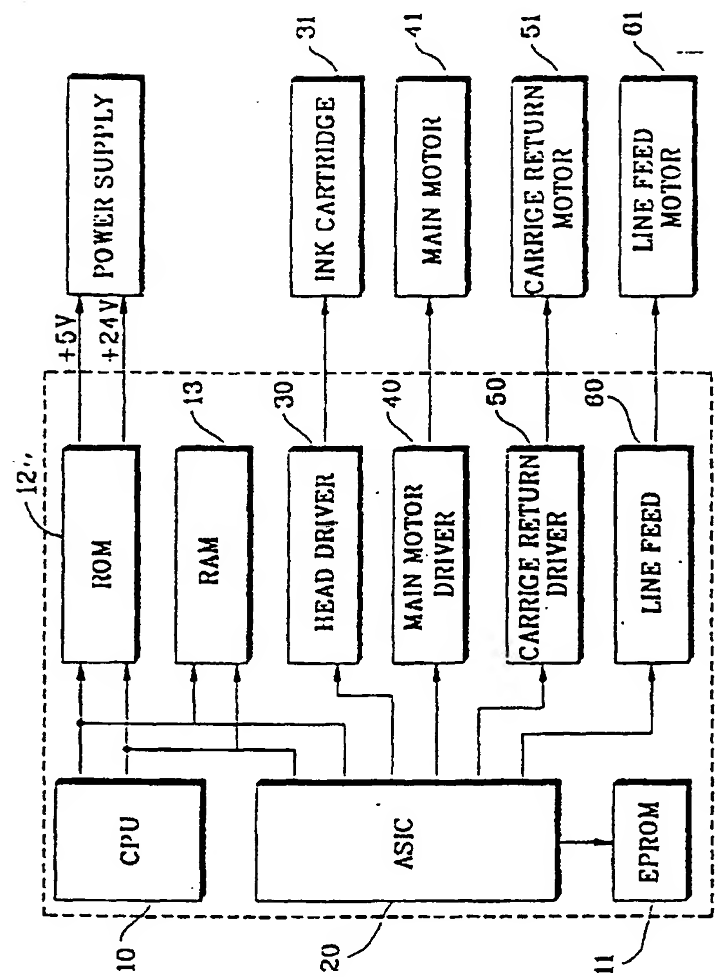
18. A method of ejecting ink from an ink-jet printer head according to any of the preceding claims comprising:

heating or cooling working fluid in the heating chamber so bubbles are created in the heater chamber thus to deform the membrane and thereby to spray ink out of the orifice.

19. An ink-jet printer head as described herein with reference to and/or as illustrated in Figures 8, 9 or 10.

20. An ink spraying method for an ink-jet printer as described herein with reference to and/or as illustrated in.Figures 8, 9 or 10.

FIG. 1


CPU
ASIC
EPROM
ROM
RAM
HEAD DRIVER
MAIN MOTOR DRIVER
CARRIGE RETURN DRIVER
LINE FEED
POWER SUPPLY
INK CARTRIDGE
MAIN MOTOR
CARRIGE RETURN MOTOR
LINE FEED MOTOR
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+24V
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61

FIG. 2

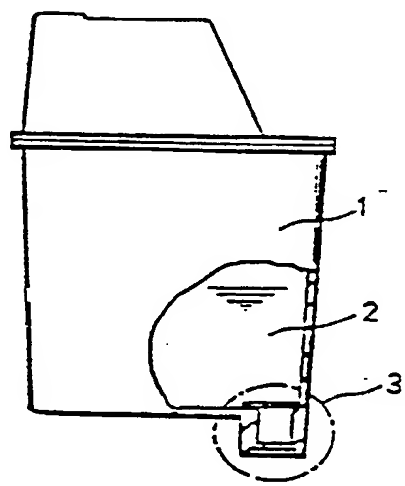


FIG. 3

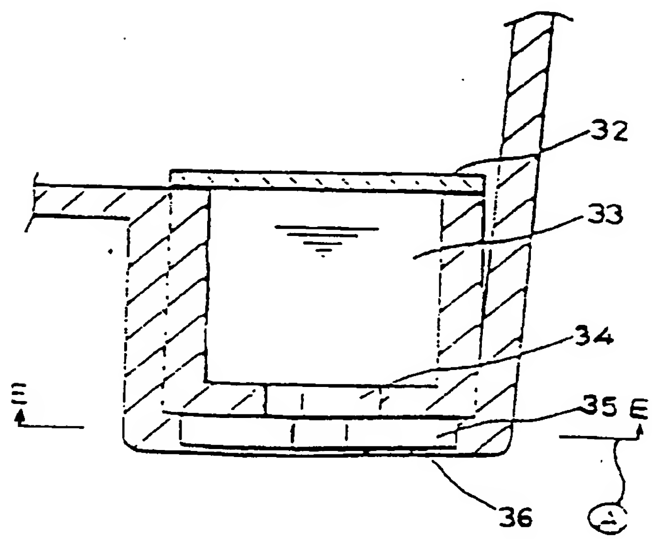


FIG. 4

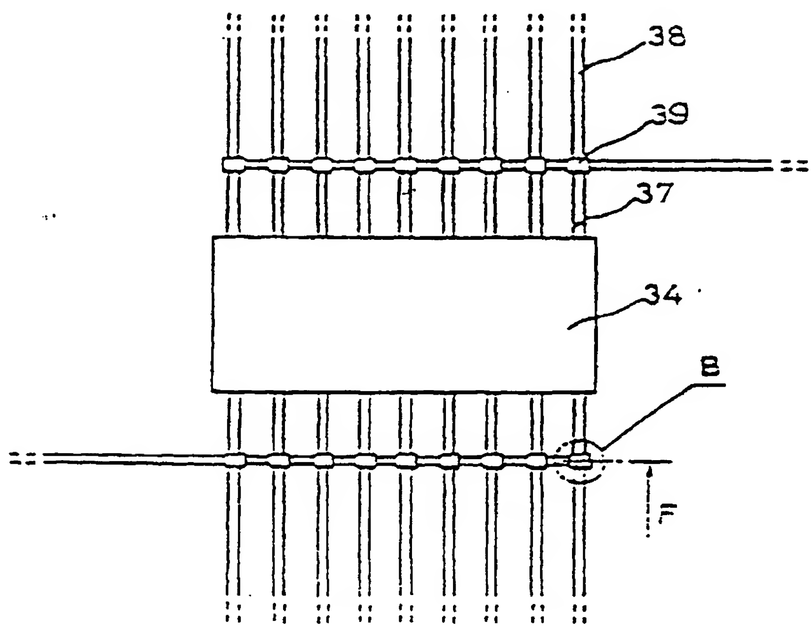


FIG. 5

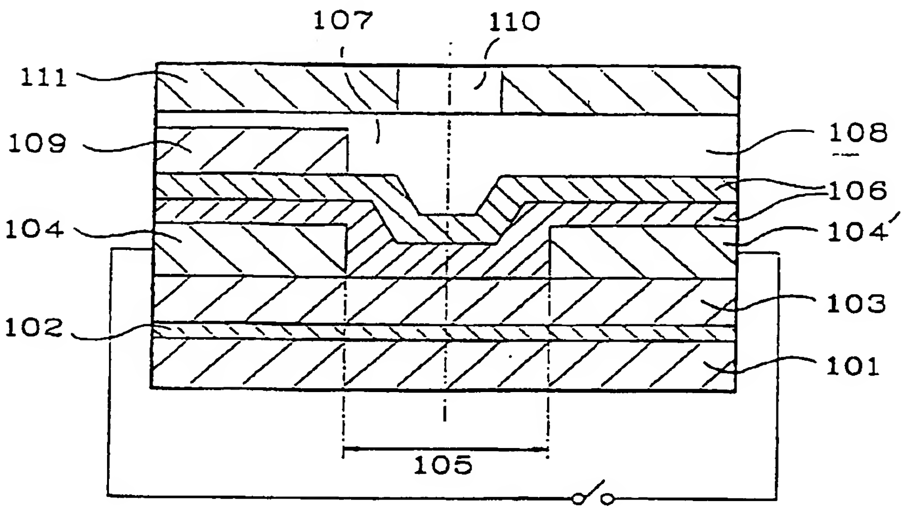
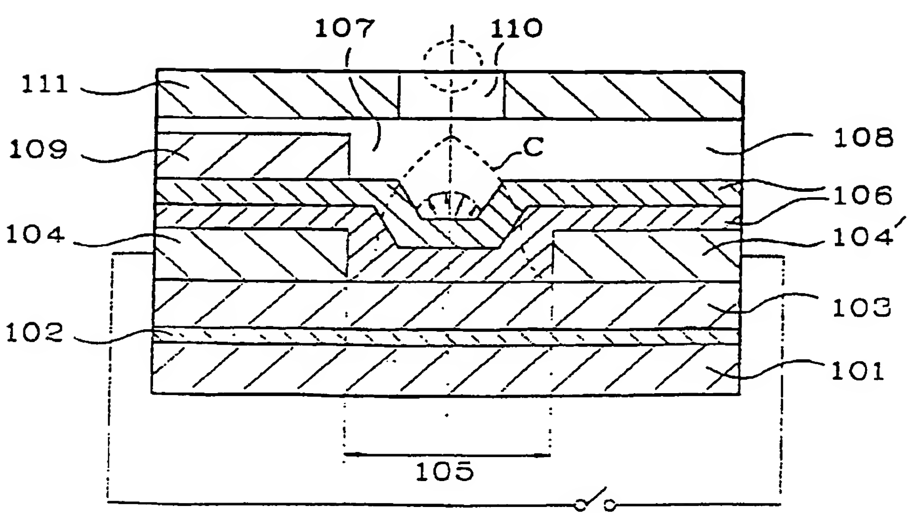

107
110
111
109
108
106
104
104'
103
102
101
105

FIG. 6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110
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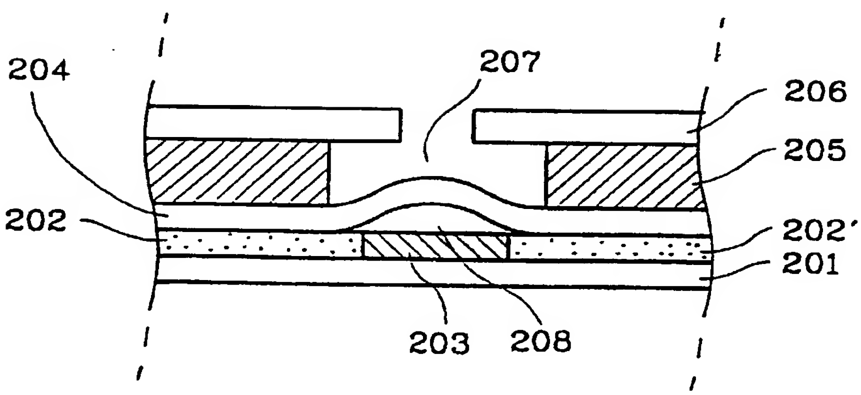
108
106
104
104'
103
102
101
105

FIG. 7



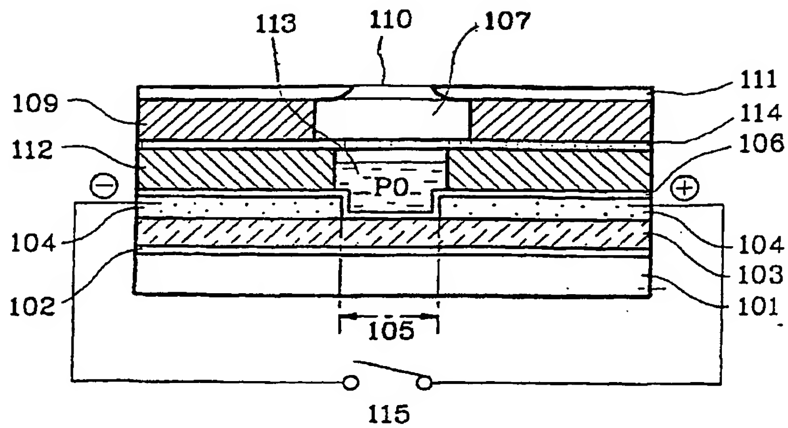


FIG. 8

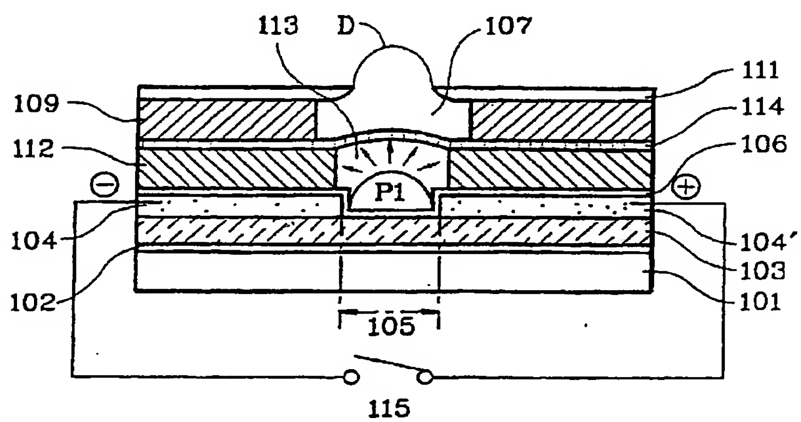


FIG. 9

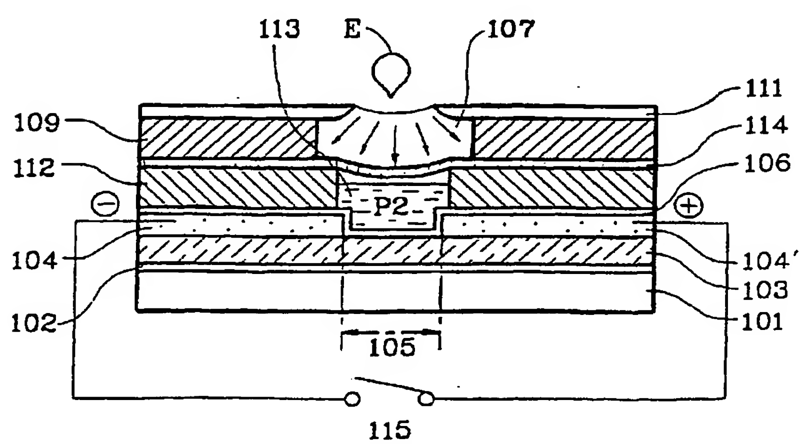


FIG. 10